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METABOLIC COST OF MILITARY PHYSICAL TASKS IN MOPP 0 AND MOPP 4

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

April 1995

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13. ABSTRACT (*Maximum 200 words*) Energy cost is an essential input to heat strain prediction models. Deficiencies exist, however, in the energy cost of performing physically demanding tasks while operating in MOPP 4 conditions. To evaluate the energy cost of soldiers wearing MOPP 4, approximately 10 men and 10 women performed 42 physical tasks (e.g. load carriage, litter carriage, lift and carry, lift only, etc.) ranging in intensity from 10% to 80% of maximal oxygen uptake. Soldiers performed each task in both MOPP 0 and MOPP 4 conditions. MOPP 4 significantly increased the oxygen uptake in 29 of 42 tasks (increases from 7% to 26%) and in 23 of 36 tasks for women (increases from 5% to 29%) compared to MOPP 0. Also, as the degree of task mobility increased, the effect of MOPP 4 increased, i.e., tasks which showed the greatest increases in oxygen uptake were those requiring continuous mobility (e.g. load carriage). Gender differences in oxygen uptake with MOPP 4 were only seen for tasks requiring continuous mobility where women increased to a greater degree than men. It is concluded that the marked increase in energy cost with MOPP 4 is attributable to the weight and/or hobbling effect of the clothing, and for tasks requiring mobility of the body across a distance, the effect is greater in women than men.

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BACKGROUND

Deficiences exist in the estimation of the metabolic cost of various military physical tasks while operating in Military Oriented Potective Posture (MOPP) conditions. Given the importance of metabolic (energy) cost for the prediction of soldier performance in the heat, it is important to quantify this variable over a wide range of military tasks from a number of different military occupational specialities, while in MOPP 4, with a greater degree of precision than is currently available. This study, therefore, determined the metabolic cost of men and women while they performed representative physical tasks that covered a wide range of exercise intensities in both MOPP 0 and MOPP 4 conditions. These data will allow for improved prediction capabilities for heat strain prediction models and tactical decision aids such as ANBACIS. It will further allow commanders to accurately utilize current guidance as contained in TBMeds, ARs, and FMs by making the adjustments required to effectively sustain performance in an NBC environment.

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The authors would like to thank the many soldiers who made this study possible. Their superior effort, cooperation and dedication were critical to the successful completion of each physical task during conditions of significant personal discomfort. The assistance and guidance provided by Mr. Bill Creech of the P^2 NBC^2 program, U.S. Army Chemical School, Fort McClellan, AL is greatly appreciated.

EXECUTIVE SUMMARY

Metabolic rate is an essential and critical input to heat strain prediction models. It is important, therefore, to precisely quantify the energy cost (oxygen uptake) of military physical tasks as a function of Military Oriented Protective Posture (MOPP). To evaluate the energy cost of soldiers wearing MOPP 4, approximately 10 men and 10 women performed for short periods of time (10-30 min) 42 occupational physical tasks (e.g., load carriage, litter carriage, lift and carry, lift only, obstacle course, grenade throw, etc.) ranging in intensity from 10% to 80% (0.5-3.4 $l \cdot min^{-1}$) of maximal oxygen uptake. Soldiers performed each task in both MOPP 0 (BDU) and MOPP 4 (BDO, gloves, boots, and M-17 protective mask). Oxygen uptake ($\dot{V}o_2$), minute ventilation (Ve), heart rate, ratings of perceived exertion, and respiratory distress were measured during performance of each task using the portable Oxylog respirometer or Douglas bag technique. Wearing MOPP 4 significantly increased the $\dot{V}o_2$ in 29 of 42 tasks for men (increases ranged from 7% to 26%) and in 23 of 36 tasks for women (increases ranged from 5% to 29%) compared to MOPP 0. Significant ($p<0.01$) correlations of 0.74 and 0.55 for men and women, respectively, were found between the metabolic cost of a task and the effect of MOPP 4; i.e., the greater the metabolic cost of a task in MOPP 0, the greater the effect of MOPP clothing. Also, in general, as the degree of task mobility increased, the effect of MOPP clothing on $\dot{V}o_2$ also increased; i.e, tasks that showed the greatest increases in $\dot{V}o_2$ were those requiring continuous mobility across a distance (e.g., load carriage, obstacle course). Women exercised at higher percentages of their maximal aerobic power than men in both the MOPP 0 and MOPP 4 conditions for nearly all tasks performed at the same workrate. However, gender differences in the increase in energy cost with MOPP 4 were seen only for tasks in the continuous mobility category; no gender differences in $\dot{V}o_2$ occurred in either stationary or intermittent mobility tasks. There were no gender differences in perceptual responses to physical task performance between MOPP 0 and MOPP 4 for any category of task. It is concluded that the marked increase in energy cost of task performance with chemical protective (CP) clothing is attributable to the weight and/or hobbling effect of the clothing, and that for tasks requiring continuous mobility of the body across a distance, the effect is greater in women than men.

INTRODUCTION

The potential for or the presence of nuclear, biological, or chemical hazards necessitates the use of protective clothing. The high insulation and low permeability of some protective clothing, such as the Army's chemical protective (CP) ensemble, severely restricts the body's heat dissipative capacity, resulting in elevated core temperature consequent to work at even mild environmental temperatures. Thus, CP clothing can significantly increase the risk of heat casualties by reducing the effectiveness of convective and evaporative heat loss to the environment. Numerous studies have documented the heat stress problems of soldiers working in warm environments wearing CP clothing (Goldman, 1963; Joy and Goldman, 1968; Armstrong et al., 1991; McLellan, 1993).

Over the past 20 years, the U.S. Army Research Institute of Environmental Medicine (USARIEM) has established a data base and developed a series of predictive equations for deep body temperature, heart rate, and sweat loss responses of clothed soldiers performing physical exercise at various environmental extremes (Pandolf et al., 1986). As a result, a heat strain model has been developed that utilizes information relative to environmental conditions, clothing, and soldier activities to predict soldier performance. For example, data from FM 3-4 (NBC Protection, 1990, Draft), based upon ambient temperature and levels of Mission Oriented Protective Posture (MOPP) at different workrate levels (light, moderate, heavy), predict the maximum number of minutes of exercise that can be sustained in a single period without exceeding a 5% risk of heat casualties. Representative physical tasks estimated as falling within these workrate levels in terms of metabolic or energy cost (oxygen uptake in watts) are also presented in FM 3-4.

The objective of the USARIEM heat strain model is to successfully predict the impact of environmental conditions on soldier performance. Prescribing maximal "safe" work times, however, requires accurate prediction models. Although attempts have been made to predict the thermal response of personnel working in CP clothing, there have been few empirical tests. Since metabolic cost is an essential and critical input to the heat strain model, it is important that it be quantified for various military tasks as a function of MOPP with a greater degree of accuracy than presently exists in FM 3-4.

In addition to the heat strain problems, the physical performance limitations imposed while wearing CP clothing have also been well documented. These include task performance decrements, increased time for task completion, and decreased work tolerance time (Louhevaara et al., 1986; Sulotto et al., 1993; White and Hodous, 1987; White et al.,1989). Many studies have also reported on the physiological and psychological reactions to wearing CP clothing and the resultant degradation of both individual and unit performance during training of combat units. These studies have been recently reviewed by Taylor and Orlansky (1993).

The two major factors affecting physiological and psychological performance of physical tasks in CP clothing are the weight and bulkiness of the clothing and the respiratory problems associated with wearing the mask. Protective clothing is known to increase the energy cost of exercise performance due to the added weight and by otherwise restricting movement. The binding or hobbling effect of multilayered clothing adds measurably to work; e.g., treadmill walking in arctic clothing (Teitlebaum and Goldman, 1972; Amor, 1973) and stepping exercise in protective clothing (Duggan, 1988), with increases of about 10% over values found for a lightly clothed individual carrying equivalent weight.

The wearing of the CP mask presents technical features that also impair exercise performance. The most important of these are the additional inspiratory and expiratory breathing resistances and the increased external dead space (Hermansen et al., 1972; Stemler and Craig, 1977; Raven et al., 1979; Louhevaara et al., 1984). Several studies have investigated the effects of added resistance to breathing during exercise at various levels of intensity. In general, a reduction in pulmonary ventilation occurs that is proportional to the increase in resistance. This can lead to the retention of carbon dioxide and increased breathing efforts with small changes in oxygen uptake at submaximal exercise intensities (Cerretelli et al., 1969; Hermansen et al., 1972; Demedts and Anthonisen, 1973). These effects are accentuated during maximal exercise in which marked reductions in maximal oxygen uptake have been found (Hermansen et al., 1972; Craig et al., 1970; Epstein et al., 1982).

A large external dead space increases the concentration of carbon dioxide in the inspired air and stimulates ventilation in order to maintain normal alveolar carbon dioxide tension at rest and during exercise. This additional effort of breathing has

been shown to increase oxygen uptake and heart rate, particularly at higher exercise intensities (Jones et al., 1971; Bartlett et al., 1972; Kelman and Watson, 1973).

Despite the plethora of knowledge on the heat strain and performance effects of wearing CP clothing, there is little quantitative information on the metabolic cost and related physiological and perceptual changes that occur during performance of physically demanding tasks in MOPP 4. The objectives of this study, therefore, were to 1) quantify the cardiorespiratory and perceptual responses of performing a variety of representative, physically demanding tasks in MOPP 4, 2) determine the effects of gender on the physiological and perceptual responses to physical task performance in MOPP 4, and 3) provide empirical metabolic cost data on representative physical tasks in MOPP 4 that can be used to improve the predictive capability of the USARIEM heat strain model.

METHODS

SUBJECTS

Thirty-two male and twenty-six female soldiers participated in this study. All soldiers were recruited from the Natick Research, Development and Engineering Center (NRDEC) test volunteer detachment. The majority of these volunteers had just completed basic and advanced individual training and were on a temporary duty status at NRDEC for the period of this study. Written informed consent was obtained from each soldier following a detailed volunteer briefing, which included a discussion of the objectives, a description of the testing procedures and physical tasks to be performed, the medical risks involved, and the advisement of the right to withdraw from participation at any time without consequence. All soldiers were medically screened prior to participating in any testing procedure.

STUDY DESIGN

Physiological testing and task performance were conducted in the laboratories of the Occupational Physiology Division, USARIEM, and on the grounds of NRDEC. An effort was made to recruit volunteers in groups of approximately 10 men and 10 women, but this was not always possible. Each group of soldiers performed 10 to 15

physical tasks in both MOPP 0 and MOPP 4 conditions as defined in FM 3-4. Tasks were categorized by workrate based on energy cost (oxygen uptake), as follows: light (<325 watts or 0.94 $l \cdot min^{-1}$), moderate (325-500 watts or 0.94-1.43 $l \cdot min^{-1}$), and heavy (>500 watts or 1.43 $l \cdot min^{-1}$). For each group of subjects, 3 to 5 tasks were selected from each workrate category for the measurement of oxygen uptake.

A cross-over design was used for data collection; i.e., half of the men and women in each group first performed a task in MOPP 0, while the other half first performed the task in MOPP 4. Each volunteer performed only 1 task per day in either the MOPP 0 or MOPP 4 condition. To minimize time effects, volunteers performed tasks in both MOPP 0 and MOPP 4 at approximately the same time each day.

REPRESENTATIVE TASKS

Tasks selected for the measurement of energy cost came from two sources: 1) Soldier's Manual of Common Tasks, Skill Level 1, STP 21-1-SMCT, Department of the Army, October 1990, and 2) Military Occupational Specialty (MOS) Physical Task List, U.S. Army Infantry School, Fort Benning, Ga., October 1978. This latter source is a compilation of data provided by each service school on the physical tasks of its respective MOSs. The standards for these tasks form the basis of the physical requirements section of each MOS described in AR 611-201. The USARIEM was previously involved in evaluating some of these tasks as the result of a Training and Doctrine Command tasking to establish physical fitness standards for MOSs (Wright and Vogel, 1978; Patton and Vogel, 1980).

Tasks were performed to standard in terms of rate, load, number of repetitions, etc. No task was performed for longer than 30 min. To minimize the possible effects of heat on the physiological and perceptual responses to exercise in CP clothing, laboratory environmental conditions were maintained between 18^{0}-22°C and 40%-55% rh. Also, no task was performed outdoors in temperatures exceeding 25°C. A detailed description of tasks within each workrate level is as follows:

<u>Light (<325 watts)</u>

<u>Task Number</u> <u>Description</u>

L-1 Maintain an M16A1 Rifle: Common Task #071-311-2025. Assemble/disassemble weapon 3 to 5 times for a duration of 5-10 min.

L-2 Prolonged standing on a circulation control point: Task #3 MOS 95B (Military Police) Skill Level 1-3. Wearing combat equipment (LBE), stand in place for 15 min.

L-3 Lift 105 mm projectiles: Task #4 MOS 55D (Missiles/Munitions) Skill level 1-5. Carry 25 kg projectiles 15 m and lift to height of 2 1/2 t truck (1.32 m), 1x/2 min for 15 min.

L-4 Relocate/establish operations: Task #2 MOS 33S (Intelligence) Skill level 1-5. Lift 22.7 kg box to height of 2 1/2 t truck (1.32 m), 1x/min for 15 min.

L-5 Lift 105 mm projectiles: Task #4 MOS 55D (Missiles/Munitions) Skill level 1-5. Carry 25 kg projectiles 15 m and lift to height of 2 1/2 t truck (1.32 m), 1x/min for 15 min.

L-6 Rig a supply load on a modular platform for airdrop: Task #1 MOS 43E (Quartermaster) Skill Level 1-5. Lift a 36 kg ammunition box from ground to height of 0.9 m and carry 6.1 m, 1x/min for 15 min.

L-7 Relocate/establish operations: Task #1 MOS 33S (Intelligence) Skill Level 1-5. Lower/lift 25 kg box to/from ground level from/to 2 1/2 t truck (1.32 m), 1x/4 min for 15 min (lift every 2 min/lower every 2 min).

L-8 Relocate/establish operations: Task #1 MOS 33S (Intelligence) Skill Level 1-5. Lower/lift 25 kg box to/from ground level from/to 2 1/2 t truck, 1x/min for 15 min (lift every 30 s/lower every 30 s).

L-9 Receive nonperishable subsistence; unload 40 ft container: Task #1 MOS 76X (Quartermaster) Skill Level 1-4. Lift 18 kg ration containers from floor to 0.9 m and carry 6.1 kg, 1x/min for 15 min.

L-10 Relocate/establish operations: Task #2 MOS 33S (Intelligence) Skill level 1-5. Lift a 22.7 kg box to the height of 2 1/2 t truck (1.32 m), 2x/min for 15 min.

L-11 Load crates of explosives onto truck: Task #5 MOS 12B (Engineers) Skill level 1-2. Lift 27.3 kg crate, carry 4 m, and load onto 2 1/2 t truck (1.32 m), 1x/min for 15 min.

L-12	Perform emergency destruction operations: Task #24 MOS 16B (Air Defense Artillery) Skill level 1-4. Lift a 6.8 kg shape charge, carry 15 m and hold at fullest upward reach for 1 min; repeat every 2 min for 15 min.
L-13	Load artillery pieces in preparation for firing: Task #8 MOS 13B (Field Artillery) Skill Level 1-2. Lift 45 kg projectiles to 1.7 m and carry 5 m, 2x/min for 15 min.

Moderate (325-500watts)

Task Number	Description
M-1	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) without rucksack, march on a level, hard surface at 1.11 m/s for 15 min.
M-2	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment with a 20 kg rucksack, march on a level, hard surface at 1.11 m/s for 15 min.
M-3	Lift, carry, and move patients: Task #7 MOS 91B (Medical) Skill Level 1-2. Given 2 person litter team, move patient weighing 68 kg over level terrain a distance of 500 m in 20 min.
M-4	Load artillery pieces in preparation for firing: Task #8 MOS 13B (Field Artillery) Skill Level 1-2. Lift 45 kg projectiles to 1.7 m and carry 5 m, 4x/min for 10 min.
M-5	Load artillery pieces in preparation for firing: Task #8 MOS 13 B (Field Artillery) Skill Level 1-2. Lift 45 kg projectiles to 1.7 m and carry 5 m, 3x/min for 10 min.
M-6	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) without rucksack, march on level, hard surface at 1.48 m/s for 15 min.
M-7	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) with a 30 kg rucksack, march on level, hard surface at 1.11 m/s for 15 min.
M-8	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (wt=7 kg), carrying an M-16 (wt=3 kg), and a 30 kg rucksack, march on level, hard surface at 1.11 m/s for 15 min.
M-9	Lift 105 mm Projectiles: Task #2 MOS 55D (Missile/Munitions)

Skill Level 1-5. Lift 25 kg projectile and carry 15 m to height of 2 1/2 t truck (1.32 m), 2x/min for 15 min.

M-10	Unload and stack paper stock: Task #2 74B (Administration) Skill Level 1-2. Lift 18.2 kg box and carry 9 m to include up stairs 2.5 m high, 1x/min for 15 min.
M-11	Relocate/establish operations: Task #1 MOS 33S (Intelligence) Skill Level 1-5. Lift 22.7 kg box to height of a 2 1/2 t truck (1.32 m), 4x/min for 15 min.
M-12	Relocate/establish operations: Task #2 MOS 33S (Intelligence) Skill Level 1-5. Lift/lower 22.7 kg box to/from 2 1/2 t truck (1.32 m), 6x/min for 10 min (lift in 10 s/lower in 10 s).
M-13	Dig individual defensive position: Task #11 MOS 11B (Infantry) Skill Level 1-5. Using entrenching tool, dig a foxhole 0.45 m deep, approximately 0.6 m by 1.8 m in sandy soil in 30 min.

Heavy (>500 watts)

Task Number	Description
H-1	Employ hand grenades: Common Task #071-325-4407. Using dummy grenades, engage a 5 m radius target, 40 m from a covered position, 3x/min for 10 min.
H-2	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment with a 20 kg rucksack, march on a level, hard surface at 1.48 m/s for 15 min.
H-3	Move under direct fire (rush and crawl): Common Task #071-326-0502. Wearing combat equipment (LBE) and carrying a weapon, conduct high crawl and rush manuevers over wooded terrain, complete 136.5 m course in 90 s, 5 times.
H-4	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) with 20 kg rucksack, march in loose sand at 0.98 m/s for 15 min.
H-5	Carry TOW equipment: Task #1 MOS 11H (Infantry) Skill level 1-4. Wearing combat equipment (LBE), carry 24.5 kg traversing unit up a grade (10%), at 0.89 m/s for 15 min.
H-6	Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5.

Wearing combat equipment (LBE) with 30 kg rucksack, march on level, hard surface at 1.48 m/s for 15 min.

H-7 Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (wt=7 kg), carrying weapon (wt=3 kg), with 30 kg rucksack, march on level, hard surface at 1.48 m/s for 15 min.

H-8 Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) with a 20 kg rucksack, march in sand at 1.31 m/s for 15 min.

H-9 Carry an M5 smoke pot in preparation of a smoke line: Task #1 MOS 54C (Chemical) Skill Level 1-2. Lift two 13.6 smoke pots, carry 30 m and lower, 4x/min for 10 min.

H-10 Lift 105 mm projectiles: Task #4 MOS 55D (Missiles/Munitions) Skill Level 1-5. Lift 25 kg projectiles and carry 15 m to height of 2 1/2 t truck (1.32 m), 4x/min for 15 min.

H-11 Lift, carry and move patients: Task #7 MOS 91B (Medical) Skill Level 1-2. Given a 4 person litter team, move patient weighing 81.8 kg over level terrain a distance of 1000 m in 30 min.

H-12 Lift, carry and move patients: Task #7 MOS 91B (Medical) Skill Level 1-2. Given a 2 person litter team, move patient weighing 68.2 kg, 100 m every 90 s for 10 min.

H-13 Carry TOW equipment: Task #1 MOS 11B (Infantry) Skill Level 1-4. Wearing full combat equipment, carry 24.5 kg traversing unit up a grade (20%), at 0.89 m/s for 15 min.

H-14 Move by foot: Task #1 MOS 11B (Infantry) Skill Level 1-5. Wearing combat equipment (LBE) without rucksack, move on a level, hard surface at 2.24 m/s for 10 min.

H-15 Lift, carry, and move patients: Task #7 MOS 91B (Medical) Skill Level 1-2. Given a 2 person litter team, carry patient weighing 68.2 kg, 27.5 m, lift to height of 2 1/2 t truck (1.32 m), return 27.5 m to retrieve next patient; complete 10 cycles in 10 min.

H-16 Move over, through and around obstacles: Common Task #071-326-0503. Wearing combat equipment (LBE), traverse a 150 m obstacle course in 2 min at constant rate; complete 5 cycles in 10 min.

In MOPP 0, soldiers wore the battledress uniform (BDU, wt=3.7 kg). In MOPP 4, the battledress overgarment (BDO) was worn over the BDU with gloves, overboots and the M-17-series protective mask (wt=9.3 kg). The latter was worn with filters inplace but without the hood.

Prior to data collection, subjects were familiarized with laboratory procedures, fitted with CP clothing and the M-17 mask, and instructed in the performance of each task. All subjects had prior experience in wearing CP clothing and in performing physical activities in the mask. Load-carriage tasks were conducted on a motor driven treadmill (Quinton Model 24-72) (Patton et al., 1990) and lift and/or lower tasks were performed using a repetitive lift device (Sharp et al., 1987). Other tasks were conducted at various sites on the grounds of NRDEC. Every effort was made to meet the specific requirements of each task to include the wearing of full combat equipment. To ensure a valid comparison between MOPP 0 and MOPP 4 for tasks that were not performed on the treadmill or with the lift device, the rate of task performance was maintained constant by a pacing device (Pacer Products, Batavia, Ill).

PHYSIOLOGICAL MEASURES

The energy cost of each task was determined by the measurement of oxygen uptake ($\dot{V}o_2$) using either the Douglas bag technique or the portable Oxylog respirometer (P.K. Morgan, Chatham, U.K.). For the former, the subject breathed through a mouth/face mask and T-shaped, two-way rebreathing valve (Hans Rudolph, Inc., Kansas City, Mo.) into respiratory tubing connected directly to the Douglas bag. Timed 30-60 s gas collections were taken. Gas volumes were then determined with a Collins chain-compensated gasometer (Warren E. Collins, Braintree, Mass.) and expired O_2 and CO_2 fractions were measured with Applied Electrochemistry S-3A (Ametek, Pittsburgh, Pa.) and Beckman LB-2 (Sensormedics, Yorba Linda, Calif.) analyzers, respectively.

The Oxylog consists of a turbine flowmeter to measure inspired ventilation volume, and expiratory tubing connected to an analyzer containing two polarographic sensors to measure inspired and expired oxygen concentrations. The analyzer was worn on the back (weight=2.6 kg) during task performance. The Oxylog has been shown to be an accurate and reliable system for the measurement of $\dot{V}o_2$, with reported differences of less than 5% compared to the Douglas bag technique (Louhevaara et al., 1985;

Figure 1. MOPP 0 configuration for measurement of oxygen uptake: mouth/face mask (A) connected to T-shaped, two-way, non-rebreathing valve; inspired tubing on subject's right is connected to turbine and expired tubing on subject's left is connected to Oxylog (B). A panel meter on the Oxylog displays $\dot{V}_E$ and $\dot{V}o_2$ in $l \cdot min^{-1}$ each minute.

A

B

Harrison et al., 1982). According to the manufacturer, the Oxylog is accurate up to ventilation volumes ($\dot{V}E$) of 80 l/min and $\dot{V}o_2$ of 3.0 l/min. Tasks estimated to approach or exceed these values were performed using the Douglas bag technique. Thus, the intensity of the task largely determined which system was used. With the Oxylog, measurements were made every minute throughout task performance, while measurements with the Douglas bag were taken every 3-4 min. In both cases, all values were averaged to determine the $\dot{V}o_2$ for that task.

In MOPP 0, subjects wore the Rudolph mouth/face mask and breathed through the T-shaped, two-way non-rebreathing valve connected to the respiratory tubing. This, in turn, was attached directly to the Douglas bag or Oxylog (Figure 1). In MOPP 4, respiratory tubing connected the outlet valve of the M-17 mask via an adapter to either the Douglas bag or Oxylog. For the latter, tubing also connected the inlet valves of the mask to the turbine (Figure 2).

Heart rate was determined by Polar Pacer Heart Rate Monitor (Polar USA, Stamford, Conn.) (see Figure 1B) and recorded at the same time as $\dot{V}o_2$ and $\dot{V}E$. In addition, perceptual category scales were used to determine ratings of perceived exertion (Robertson et al., 1979) and to assess respiratory distress (Morgan and Raven, 1985). The latter is a 7 point psychophysical scale with the odd numbers anchored with verbal descriptions, as follows: 1, "My breathing is okay"; 3, "I am starting to breathe harder"; 5, "I am not getting enough air"; 7, "I can't breathe." These perceptual responses were recorded at the completion of each task in both MOPP conditions.

To characterize the body composition and aerobic capacity of the subjects, body density and maximal oxygen uptake ($\dot{V}o_{2\ max}$) were determined prior to task performance. To minimize changes in either of these variables during the period of testing (approximately 6-8 weeks for each group), subjects were encouraged to maintain their present level of physical fitness and regular dietary habits.

Body density was determined by a standard hydrostatic weighing technique using a load cell interfaced with a desktop computer (Fitzgerald et al., 1987). Subjects were weighed wearing a bathing suit and while in the post-absorptive state. Residual lung volume was determined by the method of Wilmore et al. (1969). The mean (± SD)

Figure 2. MOPP4 configuration for metabolic measurements: respiratory tubing from outlet valve of mask (A) is connected via adapters directly to the Oxylog (B); tubing from both inlet valves (A) is connected to the turbine (B).

A

B

values and ranges for subject physical characteristics are presented in Table 1. The men were significantly younger, taller, weighed more, and had a lower percentage of body fat and a greater fat-free mass. The data for both genders were similar to those of a large age-matched Army population (Fitzgerald et al., 1986).

$\dot{V}o_{2max}$ was determined using a discontinuous, progressive treadmill protocol (Mitchell et al., 1957). Subjects ran at 2.68 $m \cdot s^{-1}$, 0% grade for 6 min after which the grade was increased to 5% and the speed held constant or increased to 2.91-3.13 $m \cdot s^{-1}$. Each subsequent bout of exercise was performed for 3 min at grades increased by 2.5% until a plateau occurred in $\dot{V}o_2$. Gas volumes and expired O_2 and CO_2 fractions were measured as previously described for the Douglas bag method. Heart rate was monitored electrocardiographically throughout the test. The mean (±SD) values and ranges for variables measured at maximal exercise are presented in Table 2. Men had a significantly greater aerobic power in both absolute terms and relative to body weight, and a greater maximal ventilation than women. The male data are in close agreement with the levels of aerobic fitness previously reported at the end of basic training (Vogel et al., 1986). The mean aerobic power for the women, however, was 10% greater than previously reported at the end of basic training (Vogel et al., 1986) and most likely reflects the increased emphasis that has been placed on aerobic fitness of women in the Army over the past 15-20 years.

STATISTICAL ANALYSIS

A two-way, repeated measures ANOVA with gender and MOPP condition as independent variables was used to examine differences in the energy cost variables ($\dot{V}o_2$, $\dot{V}_E$, heart rate) and perceptual variables; i.e., ratings of perceived exertion (RPE) and respiratory distress (RD), measured during task performance. Multiple comparisons of significant F-values were made using the Tukey test. The 0.05 level of probability was accepted as significant.

Table 1. Physical characteristics (mean±SD). *Significantly different, p<.05.

VARIABLE	MEN (n=32)	WOMEN (n=26)
Age, yrs	21.9 ± 4.1	24.2 ± 5.6*
Range	18 - 35	18 - 35
Height, cm	176.7 ± 6.0	164.0 ± 6.2*
Range	166.1 - 188.4	155.3 - 176.7
Body Mass, kg	76.7 ± 8.9	61.1 ± 6.2*
Range	64.3 - 110.1	48.1 - 76.7
Body Fat, %	16.4 ± 5.9	27.4 ± 5.9*
Range	9.1 - 28.3	14.3 - 37.0
Fat Free Mass, kg	63.8 ± 6.1	44.5 ± 5.8*
Range	57.8 - 84.8	36.2 - 53.8

Table 2. Maximal physiological data (mean±SD). *Significantly different, p<.05.

VARIABLE	MEN (n=32)	WOMEN (n=26)
$\dot{V}O_{2max}$, $l \cdot min^{-1}$	4.10 ± 0.50	2.70 ± 0.30*
Range	3.30 - 5.13	2.17 - 3.31
$\dot{V}O_{2max}$, $ml \cdot kg^{-1} \cdot min^{-1}$	53.4 ± 4.7	44.2 ± 4.1*
Range	41.4 - 60.1	38.6 - 52.5
$\dot{V}E_{max}$, $l \cdot min^{-1}$ BTPS	137.2 ± 18.0	97.9 ± 13.9*
Range	174.4 - 100.8	60.0 - 117.2
Heart Rate, $b \cdot min^{-1}$	191.8 ± 7.0	191.1 ± 7.0
Range	173 - 202	173 - 205

RESULTS

Table 3 presents a quick reference list of tasks and the number of men and women who completed each task. For the purposes of this table, the following abbreviations are used: LC=load carriage; L&C=lift and carry; LTC=litter carry; L/L= lift/lower.

Table 3. Quick reference list and number of subjects completing each task.

TASK#	DESCRIPTION	MEN	WOMEN
L-1	Maintain M-16	9	9
L-2	Prolonged standing	9	10
L-3	L&C: 25 kg, 15 m, 1x/2min	11	6
L-4	Lift: 22.7 kg, 1.32 m, 1x/min	9	12
L-5	L&C: 25 kg, 15 m, 1x/min	12	5
L-6	L&C: 36 kg, 20 ft, 1x/min	10	0

L-7	L/L: 25 kg, 1.32 m, 1x/4min	9	11
L-8	L/L: 25 kg, 1.32 m, 1x/min	12	6
L-9	L&C: 18 kg, 6.1 m, 1x/min	10	11
L-10	Lift: 22.7 m, 1.32 m, 2x/min	10	12
L-11	L&C: 27.3 kg, 4 m, 1x/min	9	9
L-12	L&C: 6.8 kg, 15 m, 1x/2min	9	10
L-13	L&C: 45 kg, 5 m, 2x/min	12	0
M-1	LC: 1.11 m/s, LBE only	9	11
M-2	LC: 1.11 m/s, 20 kg ruck	9	12
M-3	LTC: 2-person, 68.2 kg, 250 m	8	7
M-4	L&C: 45 kg, 5 m, 4x/min	12	0
M-5	L&C: 45 kg, 5 m, 3x/min	10	0
M-6	LC: 1.46 m/s, LBE only	9	13
M-7	LC: 1.11 m/s, 30 kg ruck	9	11
M-8	LC: 1.11 m/s, 10 kg LBE, 30 kg ruck	11	5
M-9	L&C: 25 kg, 15 m, 2x/min	9	9
M-10	L&C: 18.2 kg, 9 m, 1x/min	9	11
M-11	Lift: 22.7 kg, 1.32 m, 4x/min	11	9
M-12	L/L: 22.7 kg, 1.32 m, 6x/min	9	11
M-13	Dig defensive position	6	6
H-1	Employ handgrenades	8	5
H-2	LC: 1.48 m/s, 20 kg ruck	9	10
H-3	Move under direct fire (rush/crawl)	6	5

H-4	LC: 0.98 m/s, 20 kg ruck, sand	6	9
H-5	LC: 0.89 m/s, 10% grade, 24.5 kg	12	6
H-6	LC: 1.48 m/s, 30 kg ruck	10	13
H-7	LC: 1.48 m/s, 10 kg LBE, 30 kg ruck	9	8
H-8	LC: 1.31 m/s, 20 kg ruck, sand	9	9
H-9	L&C: two 13.6 kg, 30 m, 4x/min	9	10*
H-10	L&C: 25 kg, 15 m, 4x/min	10	13*
H-11	LTC: 4-person, 81.8 kg, 1000 m	10	7*
H-12	LTC: 2-person, 68.2 kg, 100 m/90 s	12	0
H-13	LC: 0.89 m/s, 20% grade, 24.5 kg	10	0
H-14	LC: 2.24m/s, LBE Only	9	9
H-15	LTC: 2-person, 68.2 kg, 27.5 m/min	6	5
H-16	Obstacle course	9	11

*Tasks were modified for women, as follows: H-9, 3x/min; H-10, 3x/min; H-11, 63.6 kg

It can be seen from Table 3 that women did not perform six tasks: 4 lift and carry, 1 load carriage, and 1 litter carry. It was felt that the heavy lifting requirement or predicted high energy cost of these tasks would place women at an undue risk for injury. Also, three tasks were modified for women as noted in the table, and in two other tasks (H-8 and H-16) women were unable to keep up the prescribed pace invalidating any gender comparison. Thus, statistical comparisons of physiological and perceptual variables between men and women were made on only 31 of the 42 tasks.

Table 4 presents mean $\dot{V}o_2$ expressed in absolute terms ($l \cdot min^{-1}$) for both MOPP 0 and MOPP 4 conditions and the percentage of increase with CP clothing in men and women. Tasks are ranked in ascending order based on male MOPP 0 values. $\dot{V}o_2$ ranged from 0.39 to 3.36 $l \cdot min^{-1}$ (9.5 to 82.0 %$\dot{V}o_2$max) and from 0.29 to 2.03 $l \cdot min^{-1}$ (10.7 to 75.2 %$\dot{V}o_2$max) for men and women, respectively. Thus, a wide range in exercise intensity characterized the tasks. The percent increase in $\dot{V}o_2$ of tasks performed by men ranged from 0.3% to 26.9% with 29 of the 42 tasks showing

significant changes. For women, the increase in Vo_2 ranged from 0.0% to 28.7% with 23 of 36 tasks showing significant increases.

Closer scrutiny of Table 4 shows that significant increases in Vo_2 occurred in 6 of 13 (46%) and 5 of 11 (45%) light (L) tasks for men and women, respectively. For the moderate (M) and heavy (H) tasks, these numbers were 9 of 13 (69%) and 14 of 16 (88%) for men and 8 of 11 (73%) and 10 of 14 (71%) for women. These data suggest that for men, at least, the greater the task intensity, the greater the likelihood that significant increases occur with CP clothing.

Table 4. Mean (±SE) values for oxygen uptake ($l \cdot min^{-1}$) ranked in ascending order by male MOPP 0 values and percentage of increase with CP clothing. *p<.05; **p<.01

		MEN			WOMEN	
TASK#	**MOPP-0**	**MOPP-4**	**%INC**	**MOPP-0**	**MOPP-4**	**%INC**
L-2	0.39±0.02	0.42±0.02	7.7*	0.29±0.02	0.29±0.03	0.0
L-3	0.49±0.02	0.51±0.02	3.9	0.42±0.03	0.45±0.01	9.1
L-7	0.54±0.02	0.58±0.02	8.6	0.39±0.01	0.40±0.02	5.1
L-4	0.58±0.02	0.59±0.02	1.7	0.46±0.01	0.50±0.01	10.5*
L-12	0.60±0.03	0.67±0.04	12.3*	0.43±0.01	0.51±0.02	18.6**
L-5	0.63±0.02	0.68±0.03	8.3	0.60±0.04	0.61±0.06	1.9
L-8	0.70±0.02	0.72±0.02	3.2	0.63±0.02	0.70±0.03	11.2*
L-9	0.71±0.03	0.80±0.04	14.0*	0.57±0.03	0.61±0.03	7.1
L-10	0.74±0.03	0.79±0.03	7.0*	0.67±0.02	0.75±0.03	13.0*
L-11	0.78±0.03	0.83±0.05	6.1	0.66±0.01	0.72±0.02	9.7**
L-13	0.82±0.02	0.88±0.02	7.2	------------	------------	-----
L-6	0.86±0.02	0.93±0.04	8.0*	-----------	------------	-----
L-1	0.88±0.04	1.04±0.08	17.3*	0.54±0.03	0.58±0.03	9.4

M-1	0.93±0.05	1.11±0.05	18.7**	0.72±0.01	0.90±0.02	23.6**
M-2	0.95±0.02	1.14±0.03	21.0**	0.87±0.03	1.04±0.04	19.9**
M-3	0.98±0.06	0.98±0.06	0.3	0.76±0.03	0.86±0.03	14.3**
M-9	1.01±0.05	1.08±0.03	8.0*	0.85±0.02	0.96±0.03	12.9**
M-7	1.07±0.02	1.28±0.06	19.2**	0.96±0.02	1.20±0.02	26.2**
M-5	1.07±0.04	1.19±0.05	11.6*	-------------	-------------	-----
M-10	1.11±0.04	1.23±0.05	11.1**	0.87±0.02	1.00±0.04	9.2**
M-6	1.12±0.04	1.41±0.06	26.9**	0.93±0.04	1.16±0.05	24.8**
M-8	1.13±0.03	1.32±0.03	17.3**	0.96±0.05	1.19±0.05	24.9**
M-11	1.14±0.03	1.18±0.02	4.2	1.02±0.03	1.10±0.04	8.3
M-4	1.29±0.03	1.40±0.03	9.1**	------------	------------	-----
M-12	1.33±0.05	1.39±0.05	4.8	1.14±0.05	1.20±0.07	5.0
M-13	1.33±0.07	1.49±0.12	12.0	0.88±0.03	0.95±0.06	7.1
H-2	1.46±0.07	1.66±0.08	14.3**	1.21±0.07	1.54±0.06	28.7**
H-4	1.47±0.06	1.68±0.03	15.1**	1.41±0.05	1.74±0.13	22.5**
H-6	1.59±0.04	1.81±0.05	14.5**	1.51±0.07	1.70±0.06	13.2**
H-1	1.61±0.10	1.65±0.09	3.8	0.89±0.05	0.96±0.06	9.2
H-5	1.71±0.04	1.84±0.04	7.4**	1.37±0.07	1.42±0.07	4.0
H-10	1.76±0.07	2.05±0.06	18.0**	1.25±0.04	1.43±0.05	15.3**
H-12	1.81±0.08	1.97±0.05	10.4*	------------	------------	-----
H-11	1.83±0.10	2.01±0.09	10.7**	1.37±0.06	1.55±0.06	13.4**
H-15	2.09±0.10	2.35±0.09	13.6**	1.76±0.05	1.93±0.05	9.2**
H-7	2.10±0.09	2.38±0.09	13.8*	1.72±0.05	1.95±0.15	13.7*

H-16	2.30±0.08	2.48±0.10	8.0^{**}	1.67±0.08	1.82±0.08	9.2^{**}
H-8	2.30±0.05	2.54±0.06	10.1^{**}	1.88±0.07	1.94±0.06	3.8
H-3	2.40±0.12	2.56±0.08	8.1	1.60±0.11	1.74±0.07	12.2
H-14	2.73±0.14	3.16±0.15	16.1^{**}	2.02±0.06	2.41±0.07	19.4^{**}
H-13	3.00±0.08	3.24±0.07	8.1^{**}	------------	------------	-----
H-9	3.36±0.13	3.67±0.16	9.4^{*}	2.03±0.08	2.12±0.08	4.4^{**}

To express the data another way, Table 5 presents the mean and percent increase in Vo_2 ($l{\cdot}min^{-1}$) between MOPP 0 and MOPP 4 for tasks divided into the different workrate categories (Light, Moderate, or Heavy).

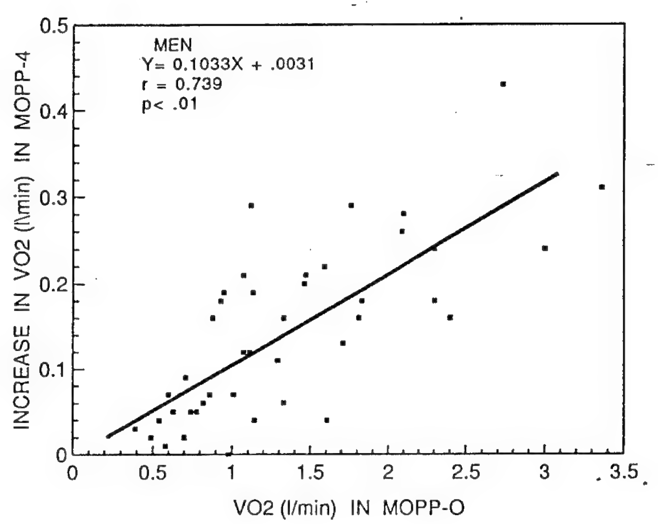
Table 5. Mean increase in Vo_2 ($l{\cdot}min^{-1}$ and %) between MOPP 0 and MOPP 4 for tasks by workrate category. Different letters denote significance (p<.01) within gender.

TASK CATEGORY	MEN	WOMEN
Light		
n	13	11
Mean ± SE	0.055 ± 0.011^{a}	0.041 ± 0.008^{a}
% Increase	8.1	8.7
Moderate		
n	13	11
Mean ± SE	0.134 ± 0.022^{b}	0.145 ± 0.021^{b}
% Increase	12.6	16.0
Heavy		
n	16	14
Mean ± SE	0.215 ± 0.019^{c}	0.183 ± 0.029^{b}
% Increase	11.3	12.7

There were no differences between genders in the mean increase in $\dot{V}o_2$ with MOPP 4 at any workrate level. In men, $\dot{V}o_2$ was significantly higher at each successive workrate level, while women showed significantly higher values in the moderate and heavy categories compared to the light category.

In Figure 3, the relationship between energy cost in MOPP 0 and the absolute ($l \cdot min^{-1}$) increase in $\dot{V}o_2$ with MOPP 4 is shown for both men and women. Significant correlations ($p<.01$) of 0.74 and 0.55 were found, respectively, again showing that the higher the energy cost of a task, the greater the physiological impact of CP clothing.

Figure 3. Relationship between energy cost in MOPP 0 and the absolute ($l \cdot min^{-1}$) increase in $\dot{V}o_2$ with MOPP 4.



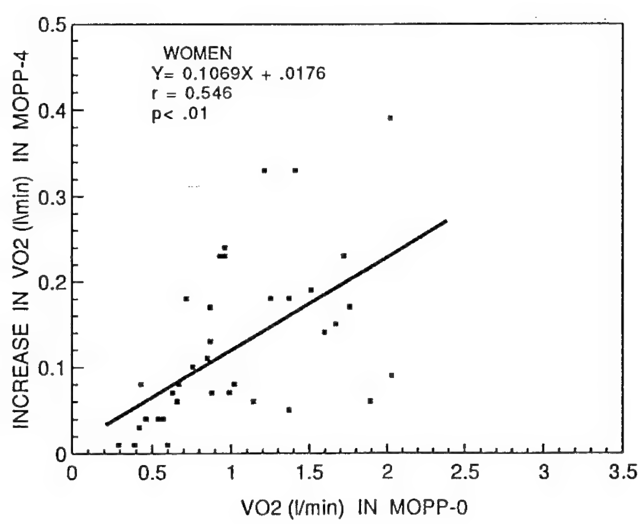


Table 6 presents the mean increase in $\dot{V}O_2$ ($l \cdot min^{-1}$) between MOPP 0 and MOPP 4 for tasks divided into three categories based on the degree of whole-body mobility involved in performance of the task: stationary tasks (S)--no mobility of the body over a distance (e.g., lift or lift/lower [n=8; L-1, L-2, L-4, L-7, L-8, L-10, M-11, M-12]); intermittent tasks (I)--mobility on an intermittent basis (e.g., lift and carry [n=16; L-3, L-5, L-6, L-9, L-11, L-12, L-13, M-3, M-4, M-5, M-9, M-10, H-1, H-9, H-10, H15]); and continuous tasks (C)--continual mobility throughout task performance (e.g., load carriage [n=17; M-1, M-2, M-6, M-7, M-8, M-13, H-2, H-4, H-5, H-6, H-7, H-8, H-11, H-12, H-13, H-14, H-16]).

Table 6. Mean increase in $\dot{V}O_2$ ($l \cdot min^{-1}$ and percentage of) between MOPP 0 and MOPP 4 by task category. *Significantly different ($p<.01$) compared to continuous category.

TASK CATEGORY	MEN	WOMEN
Stationary		
n	8	8
Mean ± SE	0.051±0.017*	0.048±0.011*
% Increase	6.8	7.8
Intermittent		
n	16	12
Mean ± SE	0.108±0.024*	0.089±0.015*
% Increase	9.0	10.1
Continuous		
n	17	15
Mean ± SE	0.218±0.017	0.202±0.026
% Increase	14.3	17.0

For both genders, it can be seen that as the degree of task mobility increases, the effect of CP clothing on energy cost is also increased. While the difference between the means of the S and I groups was not statistically significant, the mean $\dot{V}O_2$ for I

tasks was nearly twice that of S tasks. For C tasks, the mean increase in $\dot{V}o_2$ was also twice that seen with the I tasks, with the difference being significant when compared to both S and I tasks.

Tables 7, 8, and 9 present mean data for physiological and perceptual variables for each task in the L, M, and H workrate categories, respectively. For light category tasks (Table 7), $\dot{V}o_2$ expressed relative to body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) and, as a percentage of $\dot{V}o_2max$, was significantly increased in MOPP 4 as previously seen in absolute terms ($l \cdot min^{-1}$) in 6 tasks for men and 5 for women. In 9 of 11 tasks performed by both genders, the energy cost for women was at a significantly greater percentage of their maximal power than for men in both MOPP 0 and MOPP 4 conditions. In only 2 tasks (L-8 and L-12), however, was the effect of MOPP 4 significantly greater in women than men. Heart rate generally followed the same pattern as $\dot{V}o_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) for both genders, with the largest increases found in those tasks with the greatest increases in $\dot{V}o_2$. Pulmonary ventilation increased in only one task for both the men and women. Additionally, $\dot{V}E$ was significantly lower in both MOPP conditions in 6 of 11 tasks by women compared to men, but no differences were seen between genders for any task in MOPP 4.

There were no effects of CP clothing on ratings of perceived exertion or respiratory distress for men performing any of the light tasks. Women showed a significant increase in perceived exertion with MOPP 4 in 2 tasks (L-10, L-12) and in respiratory distress for only 1 task (L-10). In 7 tasks, women had higher ratings of perceived exertion than men for both MOPP conditions but in only 2 (L-9 and L-12) was the increase from MOPP 0 to MOPP 4 significantly greater in women than men. Also, in only 1 task (L-10) was the increase in respiratory distress between MOPP 0 and MOPP 4 greater in women than men.

Physiological and perceptual data for the moderate category tasks are presented in Table 8. In 9 of 13 tasks for men and 8 of 11 tasks for women, $\dot{V}o_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) and $\%\dot{V}o_2max$ were significantly increased when wearing CP clothing. In all 11 tasks where men and women were compared, women exercised at a significantly higher percentage of their maximal capacity than men in both the MOPP 0 and MOPP 4 conditions. In 4 of these tasks (M-1, M-3, M-7, and M-8) the increase in $\%\dot{V}o_2max$ between MOPP 0 and MOPP 4 was significantly greater in women than men. Again, changes in heart rate generally paralleled those seen in $\dot{V}o_2$ with significant increases

Table 7. Physiological and perceptual data for light category tasks (mean±SE).

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
L-1: Men						
MOPP0	11.0±0.6	20.1±1.0	26.7±1.5	107±4	6.3±0.3	1.3±0.2
MOPP4	12.8±0.9*	23.6±1.6*	28.8±2.2	124±3**	6.8±0.6	1.4±0.2
Women	++		++			
MOPP0	8.8±0.6	19.6±1.4	20.0±1.1	108±7	7.4±0.6	1.0±0.1
MOPP4	9.5±0.6	21.3±1.6	19.7±1.0	118±7**	7.7±0.8	1.3±0.2
L-2: Men						
MOPP0	4.9±0.2	8.9±0.3	13.7±0.4	87±3	6.0±0.0	1.0±0.0
MOPP4	5.5±0.2*	10.1±0.4*	14.1±0.5	91±2	6.0±0.0	1.0±0.0
Women			+			
MOPP0	4.6±0.2	10.4±0.4	11.6±1.0	86±4	6.0±0.0	1.0±0.0
MOPP4	4.6±0.3	10.3±0.8	10.8±0.9	95±5	6.0±0.0	1.0±0.0
L-3: Men						
MOPP0	6.7±0.2	12.7±0.5	15.3±0.7	88±3	7.8±0.4	1.4±0.2
MOPP4	6.9±0.2	13.1±0.5	16.2±0.6	95±4*	8.1±0.5	1.5±0.2
Women	++	++		++	+	
MOPP0	8.2±0.5	17.7±1.4	14.3±0.7	103±2	10.0±1.1	1.0±0.0
MOPP4	8.8±0.4	19.1±1.0	15.0±0.6	110±4	10.3±0.8	1.3±0.2

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
L-4: Men						
MOPP0	7.5±0.2	14.9±0.6	18.1±0.5	95±3	6.7±0.2	1.1±0.1
MOPP4	7.7±0.4	15.1±0.6	18.0±0.8	101±3*	7.1±0.4	1.2±0.2
Women		++	++	+	++	
MOPP0	7.8±0.4	17.8±0.6	15.1±0.8	100±3	10.8±0.8	1.4±0.2
MOPP4	8.6±0.4**	19.6±0.7**	16.3±0.8	112±4**	10.8±0.5	1.6±0.3
L-5: Men						
MOPP0	8.5±0.3	16.0±0.5	18.3±0.8	97±4	8.8±0.6	1.5±0.2
MOPP4	9.3±0.5	17.4±1.0	19.2±1.0	105±5	8.8±0.6	1.8±0.2*
Women	++	++		+		
MOPP0	11.5±0.4	24.6±1.4	19.7±0.8	115±2	10.4±0.9	1.0±0.0
MOPP4	11.9±1.2	25.3±3.0	17.6±0.9	122±5	10.6±0.8	1.0±0.0
L-6: Men						
MOPP0	11.0±0.3	21.4±0.8	24.4±0.7	104±4	9.0±0.7	1.5±0.2
MOPP4	11.9±0.5*	23.1±1.0*	25.8±0.9	113±4**	9.6±0.7	2.0±0.2
L-7: Men						
MOPP0	6.7±0.2	12.2±0.4	16.1±0.7	87±2	6.1±0.1	1.0±0.0
MOPP4	7.2±0.3	13.2±0.6	16.0±0.6	93±3*	6.1±0.1	1.0±0.0
Women	+	+	+		++	
MOPP0	6.2±0.2	13.8±0.4	13.4±0.6	87±5	8.0±0.6	1.2±0.1
MOPP4	6.4±0.3	14.5±0.6	13.7±0.6	90±5	8.3±0.6	1.3±0.2

TASK	$\dot{V}O_2$, ml·kg^{-1}	%$\dot{V}O_2$max	$\dot{V}_E$, l·min^{-1}	Heart rate	RPE, Overall	Resp. Dis.
L-8: Men						
MOPP0	9.5±0.1	17.9±0.6	20.4±0.9	100±4	9.3±0.4	1.7±0.2
MOPP4	9.8±0.3	18.5±0.8	20.6±1.0	106±4*	9.4±0.5	1.8±0.3
Women	++	++▼		++	++	
MOPP0	12.3±0.6	26.4±0.8	20.0±0.8	120±4	11.3±0.8	1.2±0.2
MOPP4	13.6±0.7*	29.3±0.6*	20.4±0.8	124±4	12.3±0.7	1.2±0.2
L-9: Men						
MOPP0	9.1±0.3	18.0±0.8	20.5±0.7	98±4	7.3±0.4	1.3±0.1
MOPP4	10.3±0.4*	20.3±1.0*	22.4±0.8*	105±2	7.0±0.6	1.4±0.2
Women		++	+	+	++▼	
MOPP0	9.9±0.6	22.7±1.2	18.1±0.6	108±3	8.9±0.4	1.2±0.1
MOPP4	10.5±0.6	24.1±1.3	18.8±0.7	116±5*	9.6±0.5	1.4±0.2
L-10: Men						
MOPP0	9.8±0.4	19.2±0.8	20.9±0.5	106±3	7.6±0.7	1.2±0.1
MOPP4	10.5±0.6*	20.5±1.1*	22.5±0.8	113±3*	8.2±0.8	1.3±0.2
Women	++	++		++	++	▼
MOPP0	11.5±0.6	26.2±0.9	20.8±0.7	120±4	10.7±0.4	1.5±0.2
MOPP4	12.8±0.4*	29.4±1.2*	21.9±0.8	126±3	12.1±0.8*	2.0±0.3*

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
L-11: Men						
MOPP0	9.6±0.4	17.7±0.5	23.0±0.5	98±1	6.5±0.2	1.1±0.1
MOPP4	10.2±0.4	18.8±0.8	22.8±1.0	108±2**	6.8±0.4	1.1±0.1
Women	+	++		++	++	+
MOPP0	10.7±0.4	23.9±1.0	22.7±0.9	113±5	11.8±0.7	1.4±0.2
MOPP4	11.7±0.5**	26.2±1.4**	22.6±0.6	126±6**	11.9±0.8	1.7±0.3
L-12: Men						
MOPP0	7.4±0.2	13.7±0.6	19.3±0.6	89±3	8.5±0.5	1.2±0.1
MOPP4	8.2±0.4*	15.3±0.8*	19.8±1.0	104±3**	9.2±0.7	1.2±0.1
Women		++▼	+		▼	
MOPP0	6.8±0.2	15.6±0.5	16.0±0.5	94±5	8.1±0.5	1.0±0.1
MOPP4	8.6±0.4**	19.4±0.7**	18.2±0.6**	103±7	10.3±0.7**	1.1±0.1
L-13: Men						
MOPP0	11.0±0.3	21.1±0.8	22.7±1.0	104±3	10.0±0.6	1.9±0.2
MOPP4	11.8±0.4	22.5±0.8	23.3±1.1	110±5	10.2±0.4	1.8±0.2

*p<.05; **p<.01 MOPP 4 versus MOPP 0.
+p<.05; ++p<.01 Women versus Men.
▼ Increase between MOPP 0 and MOPP 4 greater in Women than Men (p<.05).

Table 8. Physiological and perceptual data for moderate category tasks (mean±SE).

TASK	$\dot{V}O_2$, $ml \cdot kg^{-1}$	$\%\dot{V}O_2max$	$\dot{V}_E$, $l \cdot min^{-1}$	Heart Rate	RPE, Overall	Resp. Dis.
M-1: Men						
MOPP0	11.8±0.2	21.4±0.8	26.2±0.7	95±2	6.6±0.3	1.2±0.1
MOPP4	13.9±0.2**	25.3±0.8**	27.1±1.3	108±2**	7.1±0.6	1.4±0.2
Women		++▼				
MOPP0	11.7±0.4	26.2±0.9	23.7±0.9	103±3	6.8±0.3	1.2±0.1
MOPP4	14.4±0.3**	32.2±0.8**	26.2±0.7**	118±5**	7.7±0.4	1.5±0.2
M-2: Men						
MOPP0	12.2±0.4	23.9±0.7	27.0±0.7	101±1	8.6±0.6	1.4±0.2
MOPP4	14.8±0.5**	29.1±0.7**	30.8±1.0**	114±2**	9.4±0.9	1.7±0.4
Women	++	++		++	+	
MOPP0	14.7±0.5	33.7±1.1	27.1±1.2	122±3	11.0±0.7	1.4±0.2
MOPP4	17.6±0.7**	40.5±1.6**	29.5±1.3**	135±4**	11.7±0.3	2.0±0.3**
M-3: Men						
MOPP0	12.0±0.2	21.9±0.9	28.8±1.8	103±6	11.1±0.6	1.8±0.2
MOPP4	12.0±0.4	21.9±0.9	28.1±1.9	110±8	11.8±0.4	2.1±0.4
Women	▼	++▼				
MOPP0	11.8±0.5	25.9±0.8	27.8±1.3	111±5	11.9±0.4	1.7±0.3
MOPP4	13.5±0.5**	29.5±1.0**	29.0±1.9	121±8	12.0±0.9	1.8±0.3

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
M-4: Men						
MOPP0	17.4±0.6	33.5±1.1	37.1±1.5	130±5	12.3±0.4	2.5±0.2
MOPP4	19.1±0.7**	36.5±1.4**	38.5±1.6	140±4**	12.1±0.6	3.1±0.3
M-5: Men						
MOPP0	14.0±0.4	26.8±1.1	31.3±2.1	115±5	9.7±0.6	1.3±0.2
MOPP4	15.5±0.5*	29.8±1.6*	32.8±1.4	123±4	10.5±0.8	2.6±0.3*
M-6: Men						
MOPP0	14.4±0.4	28.4±1.1	30.3±1.0	107±2	7.5±0.5	1.2±0.1
MOPP4	18.2±0.5**	36.0±1.4**	36.8±1.3**	119±3**	8.3±0.5	1.8±0.3*
Women		++	+	++▼	++	
MOPP0	15.4±0.5	35.7±1.3	28.1±1.1	119±2	9.6±0.4	1.4±0.2
MOPP4	19.0±0.6**	44.5±1.9**	33.1±1.5**	141±4**	10.3±0.4	2.3±0.2**
M-7: Men						
MOPP0	13.9±0.4	27.3±0.7	31.0±0.7	110±3	10.0±0.9	1.6±0.3
MOPP4	16.5±0.9**	32.5±1.3**	34.6±1.3*	119±4	10.3±1.0	2.3±0.5
Women	++▼	++▼		++	++	
MOPP0	16.7±0.7	38.1±1.5	30.6±1.2	130±5	12.6±0.4	1.5±0.2
MOPP4	20.9±0.9**	48.1±2.0**	34.6±1.3**	143±4**	13.7±0.4**	2.1±0.2*

TASK	$\dot{V}O_2$, ml·kg^{-1}	%$\dot{V}O_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
M-8: Men						
MOPP0	15.2±0.6	28.7±1.2	32.0±0.7	116±5	12.2±0.4	2.2±0.2
MOPP4	17.9±0.7**	33.6±1.5**	35.2±1.1**	128±5**	13.1±0.5*	2.5±0.2
Women	++▼	++▼		++		+
MOPP0	18.6±0.9	39.5±2.4	33.6±2.4	143±7	13.9±0.8	1.5±0.2
MOPP4	23.1±1.1**	49.1±2.5**	34.8±2.0	150±5	13.9±0.5	1.9±0.3
M-9: Men						
MOPP0	12.4±0.3	23.0±1.0	27.5±1.1	104±3	7.6±0.4	1.2±0.1
MOPP4	13.4±0.4*	24.6±0.6*	28.0±0.8	112±3**	8.1±0.6	1.7±0.2*
Women	+	++		++	++	
MOPP0	13.7±0.5	30.6±1.4	28.4±0.9	124±5	11.4±1.0	1.5±0.3
MOPP4	15.5±0.7**	34.6±1.7**	29.4±0.8	137±5**	11.7±1.0	2.0±0.4*
M-10: Men						
MOPP0	13.7±0.3	25.1±0.5	29.0±0.9	109±3	6.4±0.2	1.1±0.1
MOPP4	15.3±0.2**	28.0±0.8**	30.5±1.1	120±3*	7.2±0.5	1.4±0.2
Women		++				
MOPP0	14.0±0.4	31.5±1.1	26.2±0.8	114±4	7.8±0.7	1.3±0.2
MOPP4	15.2±0.5**	34.3±1.3**	27.6±1.2	127±5**	8.6±0.8	2.0±0.3**

TASK	$\dot{V}o_2$, $ml \cdot kg^{-1}$	$\%\dot{V}o_2max$	$\dot{V}_E$, $l \cdot min^{-1}$	Heart Rate	RPE, Overall	Resp. Dis.
M-11: Men						
MOPP0	15.4±0.4	28.8±1.0	29.6±1.6	119±4	10.2±0.6	2.1±0.3
MOPP4	15.9±0.4	29.9±0.8	30.0±1.3	125±4	10.4±0.5	2.6±0.2*
Women	++	++		++	+	
MOPP0	18.0±0.7	41.0±1.0	29.3±0.7	146±4	12.0±0.6	1.8±0.3
MOPP4	19.6±1.2	44.3±1.6	30.0±1.2	151±4	13.1±0.8	2.9±0.3*
M-12: Men						
MOPP0	16.5±0.7	30.3±1.3	33.9±1.2	119±4	9.2±1.6	1.6±0.2
MOPP4	17.1±0.4	31.6±1.0	31.8±1.6	125±3	10.3±0.8*	2.0±0.2*
Women		++		+		
MOPP0	18.2±0.8	41.1±1.5	32.1±1.5	127±4	10.6±0.9	1.4±0.2
MOPP4	19.2±1.1	43.0±1.9	33.1±1.7	137±5**	11.3±0.8	1.9±0.3
M-13: Men						
MOPP0	17.1±1.1	33.2±2.5	36.6±2.7	122±5	10.7±0.7	1.8±0.3
MOPP4	19.1±1.3	36.9±2.6	39.1±3.3	131±7**	11.5±0.6	2.3±0.3
Women		+			▼	
MOPP0	17.2±0.6	36.8±1.1	28.2±1.8	128±5	10.2±0.9	1.2±0.2
MOPP4	17.8±0.4	39.3±1.0	27.8±1.3	135±5	11.0±1.0	1.7±0.3

*p<.05; **p<.01 MOPP 4 versus MOPP 0.
+p<.05; ++p<.01 Women versus Men.
▼ Increase between MOPP 0 and MOPP 4 greater in Women than Men (p<.05).

Table 9. Physiological and perceptual data for heavy category tasks (mean±SE).

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart rate	RPE, Overall	Resp.Dis.
H-1: Men						
MOPP0	19.7±0.7	35.8±1.6	42.1±3.5	124±4	9.8±1.0	1.6±0.3
MOPP4	20.2±1.0	36.7±1.4	38.6±1.9	127±4	11.6±0.8	1.7±0.3
Women	++		++			
MOPP0	13.7±0.3	33.1±1.0	27.0±1.5	109±7	11.5±1.3	1.5±0.3
MOPP4	15.6±0.9	36.2±2.7	26.7±1.0	118±8	11.4±1.0	1.8±0.4
H-2: Men						
MOPP0	18.1±0.5	33.1±1.1	37.8±1.0	117±2	8.3±0.7	1.0±0.0
MOPP4	20.7±0.3**	37.8±1.4**	40.3±1.4*	133±4**	9.5±0.9*	1.6±0.2*
Women	▼	++▼		++		
MOPP0	19.4±1.3	42.5±2.6	37.5±1.9	131±5	9.0±0.8	1.3±0.2
MOPP4	24.7±1.2**	54.0±2.2**	42.2±1.2**	154±5**	10.8±0.9*	2.1±0.3*
H-3: Men						
MOPP0	30.3±0.7	59.2±2.7	61.3±2.8	162±6	12.8±0.9	3.0±0.3
MOPP4	32.7±1.0	63.6±2.5	65.9±3.6	168±3	14.0±1.1	4.2±0.3*
Women		+	++			
MOPP0	30.6±1.6	65.6±3.7	52.1±3.3	174±2	12.4±0.7	2.4±0.2
MOPP4	34.1±3.3	72.4±6.0	51.5±3.3	172±3	13.4±0.5*	3.2±0.4

TASK	$\dot{V}o_2$, l·min^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
H-4: Men						
MOPP0	19.1±1.0	36.7±2.6	37.1±1.6	119±4	10.2±0.3	1.7±0.3
MOPP4	21.8±0.8*	41.8±2.2**	40.2±2.2	131±6*	11.0±0.6	2.2±0.3
Women	++	++		++	++	
MOPP0	25.6±1.0	56.8±1.8	38.4±1.3	144±3	12.3±0.4	2.1±0.4
MOPP4	31.1±1.1**	69.5±4.0**	40.3±2.4	157±4**	13.3±0.5*	3.0±0.4*
H-5: Men						
MOPP0	23.2±0.4	43.5±1.0	41.3±1.6	126±4	10.1±0.4	1.9±0.3
MOPP4	24.7±0.4**	46.7±1.2**	43.4±2.1	138±4**	11.3±0.4*	2.7±0.2**
Women	++	++		++		
MOPP0	26.1±0.3	56.9±1.7	44.1±2.4	148±4	11.5±0.8	1.1±0.1
MOPP4	27.3±0.8	59.1±1.1	39.1±1.8	161±3*	12.6±0.6*	2.5±0.1**
H-6: Men						
MOPP0	21.1±1.0	40.8±2.0	42.6±1.5	126±5	11.0±0.6	1.7±0.2
MOPP4	24.0±1.2**	46.6±2.3**	45.6±1.6	141±6**	12.7±1.1*	2.8±0.5*
Women	+	++		++	+	
MOPP0	25.3±1.2	58.3±2.9	48.0±2.7	151±5	13.3±0.5	2.4±0.3
MOPP4	28.5±1.2**	65.5±2.7**	49.6±2.5	168±3**	15.0±0.5**	3.5±0.4*

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
H-7: Men						
MOPP0	25.7±0.5	47.7±1.3	54.7±3.1	142±3	10.7±0.9	1.5±0.3
MOPP4	29.4±0.7**	54.3±1.7**	62.4±2.9**	162±3**	13.9±0.4**	2.8±0.3**
Women		++			++	
MOPP0	27.5±1.5	59.9±2.6	57.9±4.1	160±8	14.9±0.9	2.2±0.3
MOPP4	31.0±1.3**	68.0±2.8**	60.0±2.9	167±6*	15.9±0.6	2.9±0.4*
H-8: Men						
MOPP0	29.7±0.5	58.8±1.8	57.2±1.8	149±5	10.7±0.7	2.1±0.4
MOPP4	32.7±1.2**	64.7±1.8**	59.3±2.5	156±6	11.9±0.9	3.8±0.3**
Women		++		++	++	
MOPP0	30.9±0.6	71.1±2.2	62.2±2.2	173±4	14.0±0.4	2.4±0.4
MOPP4	32.1±0.6	73.6±2.0	58.9±1.6	173±3	14.3±0.5	3.6±0.4
H-9: Men						
MOPP0	41.4±1.1	76.2±1.8	104.8±7.6	167±3	12.4±0.9	3.0±0.4
MOPP4	45.4±1.6*	83.1±1.8*	103.4±5.1	171±3	14.9±0.9*	3.8±0.3*
Women	##					
MOPP0	33.1±0.9	74.1±1.7	71.3±4.9	170±5	10.7±0.8	2.5±0.3
MOPP4	34.5±1.0*	77.2±1.3**	70.8±3.3	176±2	12.0±0.8*	3.7±0.4**

TASK	Vo_2, ml·kg^{-1}	%Vo_2max	V_E, l·min^{-1}	Heart Rate	RPE, Overall	Resp. Dis.
H-10: Men						
MOPP0	22.9±1.2	44.8±2.8	46.4±2.5	135±5	11.5±0.8	2.1±0.3
MOPP4	27.1±1.5**	52.1±2.6**	53.7±2.6**	147±5**	12.2±0.7	3.8±0.5*
Women	##					
MOPP0	20.8±0.9	48.0±2.0	40.2±1.7	157±4	12.5±0.5	2.2±0.3
MOPP4	23.7±0.7**	54.8±1.7**	41.7±1.2	165±2**	13.5±0.5*	3.1±0.3**
H-11: Men						
MOPP0	23.9±1.7	46.6±2.1	54.2±2.9	142±6	13.1±0.9	2.5±0.4
MOPP4	26.1±1.3**	51.1±1.4**	57.0±2.6	156±5**	13.9±0.8	3.6±0.4*
Women	##					
MOPP0	25.0±1.2	54.3±2.0	51.5±2.2	160±5	14.1±0.8	2.6±0.3
MOPP4	28.5±1.2**	61.5±2.1**	52.7±2.2	171±2*	15.1±0.9*	3.3±0.3**
H-12: Men						
MOPP0	24.6±1.1	46.8±2.4	47.3±2.2	137±6	12.2±0.6	3.1±0.2
MOPP4	26.8±0.7*	50.9±1.5*	52.8±2.4**	148±4**	13.5±0.9*	3.3±0.2
H-13: Men						
MOPP0	39.0±0.8	74.8±2.2	86.8±4.6	173±3	13.6±0.6	2.9±0.2
MOPP4	42.4±1.1**	80.7±1.9**	95.1±3.8*	182±2**	16.3±0.5**	4.6±0.3**

TASK	$\dot{V}o_2$, ml·kg^{-1}	%$\dot{V}o_2$max	$\dot{V}_E$, l·min^{-1}	Heart rate	RPE, Overall	Resp. Dis.
H-14: Men						
MOPP0	33.5±0.6	61.9±1.9	66.6±5.6	150±4	9.9±0.7	1.6±0.2
MOPP4	38.7±0.8**	71.8±2.4**	75.3±4.5*	166±3**	12.2±0.8**	2.6±0.3**
Women		++▾		+		
MOPP0	31.4±0.7	69.9±1.5	62.5±3.5	162±4	9.4±0.8	1.4±0.2
MOPP4	37.5±0.8**	83.4±1.5**	71.8±2.3**	177±3**	12.4±0.8**	2.8±0.3**
H-15: Men						
MOPP0	27.0±1.8	51.8±3.9	56.2±3.4	146±8	11.0±1.0	2.0±0.4
MOPP4	30.2±2.2*	58.0±4.2*	59.1±1.5	160±8**	12.8±0.5	3.7±0.4*
Women	+	++		+	+	
MOPP0	33.8±1.6	71.9±3.2	61.2±1.8	169±4	14.4±0.5	2.6±0.2
MOPP4	37.1±2.1*	78.7±3.7*	61.6±3.9	176±3	14.4±0.5	3.2±0.2
H-16: Men						
MOPP0	29.5±1.0	58.4±1.3	64.7±2.7	153±3	10.6±1.0	2.9±0.4
MOPP4	31.9±0.8*	62.9±1.6*	67.9±2.9	161±4	11.6±0.8	4.2±0.3*
Women		++		+		
MOPP0	28.7±1.1	65.8±2.3	54.5±2.0	160±4	12.3±0.6	2.8±0.3
MOPP4	31.3±0.8**	71.5±1.9**	56.8±1.7	172±3**	13.2±0.7	3.6±0.3*

*p<.05; **p<.01 MOPP 4 versus MOPP 0; +p<.05; ++p<.01 Women versus Men.
▾ Increase between MOPP 0 and MOPP 4 greater in Women than Men (p<.05).
No comparisons made between Women and Men.

occuring in 8 tasks for men and 7 for women. Gender comparisons showed that heart rate was significantly higher in women for 7 tasks in both MOPP conditions, but in only task M-6 was the increase with MOPP 4 greater than for men.

With respect to $\dot{V}E$, both genders showed significantly higher values in 4 tasks in MOPP 4 compared to MOPP 0. Thus, $\dot{V}E$ does not reflect changes seen in $\dot{V}o_2$ and heart rate due presumably to the effects of mask resistance on ventilation. No gender differences were seen in ventilation with respect to the MOPP 4 condition.

Ratings of perceived exertion were significantly higher in only 1 task for men (M-8) and women (M-7) in MOPP 4 compared to MOPP 0. Women had higher ratings than men in 5 tasks in both MOPP conditions, but there were no effects of MOPP 4 between genders for any of the tasks.

Men and women had significantly higher ratings of respiratory distress in 5 and 6 tasks, respectively, in MOPP 4 compared to MOPP 0. In one task (M-8), women rated respiratory distress significantly lower than men in both MOPP conditions. There were no significant gender differences in respiratory distress with MOPP 4 for any task.

Table 9 presents the physiological and perceptual data for the H category tasks. Both $\dot{V}o_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) and $\%\dot{V}o_2max$ were increased in 14 of 16 tasks for men and 10 of 14 tasks for women in MOPP 4 compared to MOPP 0. Percentage of $\dot{V}o_2max$ was significantly higher in both MOPP conditions in women compared to men for 10 of 11 tasks where gender comparisons were made. In 2 of these tasks (H-2 and H-14), the increase in the women's response to MOPP 4 was significantly greater than that of men. Heart rate again followed a similar pattern to that of oxygen uptake in that significant increases were seen in 11 of 16 tasks for men and 9 of 14 tasks for women. In 8 tasks, women's heart rate was significantly greater than the men's in both MOPP conditions. However, in no task was the increase with CP clothing significant between genders.

Pulmonary ventilation increased significantly in 5 of 16 tasks for men and in only 2 of 14 tasks for women. In 3 tasks, $\dot{V}E$ was significantly lower in women in both MOPP conditions, but in no task were there any effects of gender with CP clothing.

In 8 of 16 tasks for men and 9 of 14 tasks for women, RPE was significantly higher

in MOPP 4 compared to MOPP 0. In two tasks, women had higher ratings than men in both MOPP conditions, but there was no difference in RPE with CP clothing between genders for any task.

Men had higher ratings of respiratory distress in 13 of 16 tasks and women in 10 of 14 tasks comparing MOPP 4 to MOPP 0. There were no differences in respiratory distress between genders for any task in either MOPP condition or in the increase seen with MOPP 4.

Table 10 presents a summary of the number and percentage of tasks from each workrate category that showed significant increases in physiological and perceptual variables between MOPP 0 and MOPP 4 for both men and women and between genders. It is readily apparent, as previously shown in Tables 7-9, that the higher the workrate category, the greater the number of tasks with significant increases in both physiological and perceptual variables in MOPP 4 compared to MOPP 0. However, there does not appear to be differences among workrate categories in terms of the number of tasks that showed significant differences in the way women responded compared to men.

In Table 11, the mean increase in $\%\dot{V}o_2max$ from MOPP 0 to MOPP 4 for tasks in each of the three task mobility categories (Stationary, Intermittent, Continuous) is presented for both men and women. No gender differences in $\%\dot{V}o_2max$ were seen for either the stationary or intermittent task categories. However; in tasks requiring continuous whole-body mobility throughout task performance (load carriage, obstacle course, etc.), women displayed a significantly greater difference between MOPP 0 and MOPP 4 compared to men. The number of tasks where women showed a significantly greater response to MOPP 4 than men were 1 of 8, 2 of 10, and 5 of 13 for the stationary, intermittent, and continuous categories, respectively.

Table 12 presents the workrates in watts ($1\ l\cdot min^{-1}\ \dot{V}o_2=349$ watts) for all physical tasks by workrate category for MOPP 0 using the male data. In addition, the increase in watts that would occur in MOPP 4 as calculated from the regression equation in Figure 3 ($y = 0.1033x + 0.0031$) is presented. Task intensity increased an average of 25, 47, and 76 watts, respectively, for the light, moderate and heavy categories with MOPP 4.

Table 10. Summary of number of tasks with significant increases between MOPP 0 and MOPP 4 (#/Total = number of significant tasks/total number of tasks).

	MEN		WOMEN		MEN VS WOMEN	
LIGHT	**#/total**	**%**	**#/total**	**%**	**#/total**	**%**
$\dot{V}o_2$, ml·kg^{-1}·min^{-1}	6/13	46	5/11	45	0/11	0
%$\dot{V}o_2$max	6/13	46	5/11	45	2/11	18
$\dot{V}$E, l·min^{-1}	1/13	8	1/11	9	0/11	0
Heart Rate	9/13	69	4/11	36	0/11	0
RPE	0/13	0	2/11	18	2/11	18
Resp. Dis.	1/13	8	1/11	9	1/11	9
MODERATE						
$\dot{V}o_2$, ml·kg^{-1}·min^{-1}	9/13	69	8/11	73	3/11	27
%$\dot{V}o_2$max	9/13	69	8/11	73	4/11	36
$\dot{V}$E, l·min^{-1}	4/13	31	4/11	36	0/11	0
Heart Rate	8/13	62	7/11	64	1/11	9
RPE	1/13	8	1/11	9	0/11	0
Resp. Dis.	5/13	38	6/11	55	0/11	0
HEAVY						
$\dot{V}o$, ml·kg^{-1}·min^{-1}	14/16	88	10/14	71	1/11	9
%$\dot{V}o_2$max	14/16	88	10/14	71	2/11	18
$\dot{V}$E, l·min^{-1}	5/16	31	2/14	14	0/11	0
Heart Rate	11/16	69	9/14	64	0/11	0
RPE	7/16	44	9/14	64	0/11	0
Resp. Dis.	13/16	81	10/14	71	0/11	0

Table 11. A comparison of the mean increase in $\%\dot{V}O_2max$ from MOPP 0 to MOPP 4 between genders by task mobility category. *p<.01

TASK CATEGORY	MEN	WOMEN
Stationary (n=8)		
Mean ± SE	1.28 ± 0.35	1.88 ± 0.38
Intermittent (n=10)		
Mean ± SE	1.84 ± 0.55	2.99 ± 0.55
Continuous (n=13)		
Mean ± SE	5.41 ± 0.50	8.09 ± 0.96*

Table 12. Workrates in watts (W) of physical tasks by category (based on male data).

CATEGORY LIGHT (< 325W)	WORKRATE (W) MOPP 0	 MOPP 4*
L-2: Standing in foxhole/guard duty	135	150
L-3: Lift and carry, 25 kg, 15 m, 1x/2min	170	189
L-7: Lift and lower, 25 kg, 1.32 m, 1x/4min	187	207
L-4: Lift 22.7 kg, 1.32 m, 1x/min	201	223
L-12: Lift and carry, 6.8 kg, 15 m, 1x/2min	208	231
L-5: Lift and carry, 25 kg, 15 m, 1x/min	242	266
L-8: Lift and lower, 25 kg, 1.32 m, 1x/min	246	273
L-9: Lift and carry, 18 kg, 6.1 m, 1x/min	247	274
L-10: Lift 22.7 kg, 1.32 m, 2x/min	256	284
L-11: Lift and carry, 27.3 kg, 4 m, 1x/min	270	299
L-13: Lift and carry, 45 kg, 5m, 2x/min	284	314
L-6: Lift and carry, 36 kg, 6.1 m, 1x/min	298	330
L-1: Maintain M-16 rifle	304	337

Table 12. (Continued) Workrates in watts (W) of physical tasks by category.

<u>MODERATE (325-500W)</u>		
M-1: Load carriage, 1.11 m/s, LBE only	325	359
M-2: Load carraige, 1.11 m/s, 20 kg load	330	365
M-3: Two-person litter carry, 68.2 kg, 250 m	339	375
M-9: Lift and carry, 25 kg, 15 m, 2x/min	349	386
M-7: Load carriage, 1.11 m/s, 30 kg load	370	409
M-5: Lift and carry, 45 kg, 5 m, 3x/min	370	409
M-10: Lift and carry, 18.2 kg, 9 m, 1x/min	384	424
M-6: Load carriage, 1.46 m/s, LBE only	388	429
M-8: Load carriage, 1.11 m/s, 40 kg load	391	432
M-11: Lift 22.7 kg, 1.32 m, 4x/min	394	436
M-4: Lift and carry, 45 kg, 5m, 4x/min	446	493
M-12: Lift and lower, 22.7 kg, 1.32 m, 6x/min	460	509
M-13: Dig defensive position	460	509
<u>HEAVY (>500w)</u>		
H-2: Load carriage, 1.48 m/s, 20 kg load	505	558
H-4: Load carriage, 1.0 m/s, 20 kg load, sand	509	563
H-6: Load carriage, 1.48 m/s, 30 kg load	550	608
H-1: Employ handgrenades	557	616
H-5: LC, 0.9 m/s,10 % grade, 24.5 kg	592	654
H-10: Lift and carry, 25 kg, 15 m, 4x/min	609	673
H-12: Two-person litter carry, 68.2 kg, 100 m	626	692
H-11: Four-person litter carry, 81.8 kg, 1000 m	633	700
H-15: Two-person litter carry, 68.2 kg, 27.5 m	723	799
H-7: Load carriage, 1.48 m/s, 40 kg load	727	803
H-16: Obstacle course	796	879
H-8: Load carriage, 1.31 m/s, 20 kg load, sand	796	879
H-3: Move under direct fire (rush/crawl)	830	917
H-14: Load carriage, 2.24 m/s, LBE only	945	1044
H-13: Load carriage, 0.9 m/s, 20 % grade, 54 lb	1038	1146
H-9: Lift and carry, two 13.6 kg, 30 m, 4x/min	1162	1283

*Increase with MOPP 4 calculated from male regression equation in Figure 2.

DISCUSSION

It is well recognized that wearing chemical protective clothing may protect the wearer, but it also results in impairment of physical performance. Many published reports from combined arms exercises, field trials, and laboratory studies have documented the degradation of both individual and unit performance (Taylor and Orlansky, 1993). Indeed, such physical performance limitations as increased time for task completion, task performance decrements, and decreased work tolerance time have been demonstrated (Sulotto et al., 1993; White et al., 1989). The principal causes of such performance degradation are: heat stress due primarily to the weight, insulation, and low moisture vapor permeability of the overgarment; reduced manual dexterity due to constraints imposed by gloves, overgarment and boots; restricted vision and communication due to the mask; and respiratory stress due to air resistance of the mask, filters and outlet valves. Of the above, the factor most extensively investigated has been heat stress of which considerable research has documented the physical performance and associated heat tolerance problems of soldiers exercising in warm environments wearing CP clothing (Armstrong et al., 1991; McClellan 1993).

Despite the large body of knowledge on the effects of CP clothing on performance, there is little quantitative information as to the metabolic cost and related physiological and perceptual changes with wearing U.S. military CP clothing during dynamic exercise under conditions where heat stress is not a significant factor. This study quantifies the cardiorespiratory and perceptual responses of performing a variety of representative, physically demanding military tasks in MOPP 4 under thermoneutral conditions.

The tasks performed in this study were classified as light, moderate and heavy, in accordance with the workrate levels defined in FM 3-4 (NBC Protection, 1990, Draft). In addition, where applicable, tasks were also classifed by the degree to which whole-body mobility was involved in task performance: Stationary, Intermittent, and Continuous. These classification schemes will be referred to throughout this discussion. Also, women performed most of the tasks that men performed so gender comparisons could be made. As previously mentioned in the results section, there were a few tasks that women did not perform due to the heavy lifting requirement or

high aerobic demand.

Over the range of exercise intensities employed during task performance (approximately 10% to 80% of $\dot{V}o_2max$ for men and women), energy cost increased between 0% and 29%. For men, significant increases were seen in 29 of 42 (69%) tasks and for women in 23 of 36 (64%) tasks. The relationship between energy cost in MOPP 0 and the increase with MOPP 4 was significant for both men and women, indicating that the greater the intensity of the task, the greater the physiological impact of wearing CP clothing. We have recently demonstrated that the contribution of the mask to the increase in $\dot{V}o_2$ with MOPP 4 during moderate exercise is relatively slight (Patton et al., 1995), suggesting that any increase is due to the overgarment, overboots and gloves. It has been shown that various protective clothing ensembles increase the metabolic cost of performing walking and stepping tasks by adding weight and by otherwise restricting movement (Duggan, 1988; Teitlebaum and Goldman, 1972). Indeed, the latter authors reported that the energy cost of walking is significantly greater when multilayered clothing ensembles are worn compared to carrying equivalent weight on the torso. This suggests that some of the increased energy cost can be attributed to the hobbling or binding effect of the clothing, caused by its bulkiness and stiffness, which can interfere with joint movements, and/or to the frictional resistance that results from clothing layers sliding over one another.

In view of the increased numbers of women involved in combat support and combat service support roles and the fact that women have been involved in combat situations in which a substantial chemical threat existed, an increased emphasis on potential differences between genders to performance in MOPP clothing is necessary. However, data comparing physical performance differences between men and women in MOPP 4 have been limited to performance during heat stress. Laboratory studies (Rakaczky, 1981) suggest differences between men and women in physiological tolerance to heat stress, with female tolerance being lower. This finding, however, has not been established incontrovertibly. Gender comparisons of physiological and perceptual responses to performance in MOPP 4 are virtually nonexistent. The present study, therefore, is unique in assessing the effects of MOPP 4 between genders during physical task performance.

In nearly all tasks (30 of 31) where comparisons were made between genders,

women exercised at a significantly higher percentages of their maximal capacity in both MOPP 0 and MOPP 4. This was not surprising due to the much smaller size and lower maximal oxygen uptakes of women compared to men (Vogel et al., 1986) and the fact that both men and women performed the tasks at the same rates and conditions. In analyzing the gender data on the increase in Vo_2 between MOPP 0 and MOPP 4, it was found that the increase was greater for women than for men in only a few tasks (i.e., MOPP 4 had a greater effect on women than men) and that this was largely confined to tasks from the continuous mobility group. This suggests that only when continuous mobility of the whole-body is involved in task performance (load carriage, road marches, obstacle course, etc.) are women affected differently than men when wearing CP clothing. While it would be expected that the generally smaller stature and weight of women would result in the weight of MOPP clothing imposing a more severe strain on women than men, this appears to be the case only for continuous mobility tasks. Therefore, it is apparent that both stationary (lift/lower) and intermittent (lift and carry) type tasks do not result in significant differences between genders in terms of physiological and perceptual responses to physical performance in MOPP 4.

CONCLUSIONS

1. The weight and/or hobbling effect of CP clothing significantly increased the metabolic demands in 29 of 42 physical tasks for men (increases ranged from 7.0% to 26.0%) and in 23 of 36 tasks for women (increases ranged from 5% to 29%).

2. The greater the metabolic cost of a task (light to moderate to heavy), the greater the effect of CP clothing; significant positive relationships were found between the metabolic cost in MOPP 0 and the increase with MOPP 4 for both men (r=0.74) and women (r=0.55).

3. As the degree of task mobility increased (stationary to intermittent to continuous), the effect of CP clothing on metabolic cost also increased for both men and women.

4. The metabolic cost of task performance was greater for women than for men in both the MOPP 0 and MOPP 4 conditions due to the lower maximal oxygen uptakes of women.

5. Gender differences in metabolic cost of physical task performance in CP clothing were only demonstrated for those tasks requiring continuous mobility in which clothing weight and hobbling effects may increase energy expenditure to a greater degree in women than men.

6. Physical tasks belonging to either the stationary or intermittent categories do not result in gender differences in the metabolic cost of task performance as a result of wearing MOPP 4.

7. There were no gender differences in perceptual responses (ratings of perceived exertion or respiratory distress) to physical task performance when going from MOPP 0 to MOPP 4 for any category of task.

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